## FOOD SECURITY AND CONFLICTS: A STATISTICAL APPROACH

Daniel Vidal Pérez*
Matheus Henrique Junqueira Saldanha**

**ABSTRACT**
History tells us that the lack of food - or only the fear of its loss - plays a central role in the occurrence of human conflicts. Despite this, food is one of the biggest and least recognized drivers of global security. Now, at the beginning of the 21st century, humanity is faced - again - with the challenge of how to feed a growing urban population. Most of the literature on the subject focuses on qualitative links between variation in food availability/affordability and violence, but is limited to countries in conflict. Thus, the objective of the present work was to use a statistical approach in an attempt to find some pattern or mathematical relationship between a selected number of variables that capture the social, environmental and economic factors that make the occurrence of conflicts and violence more likely. Analysis of the data suggests that conflicts can be better explained by considering the interactions between terrorism, food security, and people's income.
**Keywords:** Hunger. Instability Terrorism.

### 1 INTRODUCTION

"Where there is conflict, there is hunger. And where there is hunger, there is often conflict." This statement was issued by Executive Director David Beasley when he received the 2020 Nobel Peace Prize on behalf of the WPF (United Nations World Food Program – UN, 2020, our translation). The literature that supports and illustrates this two-way path is abundant. Cohen and Pinstrup-Andersen

* Researcher, Brazilian Agricultural Research Corporation (Embrapa-Solos). Senior volunteer researcher in the Biodefense and Food Safety subgroup of the Naval War College Simulations and Scenarios Laboratory (LSC/EGN). Master in Soil Science. Doctorate in Inorganic Analytical Chemistry from the Pontifical Catholic University of Rio de Janeiro (PUC-Rio) in 2002. Contact: daniel.perez@embrapa.br; http://orcid.org/0000-0003-4336-2223
** Specialist, Department of Computer Science, Institute of Mathematics and Computer Science. Contact: matheus.saldanha@usp.br; https://orcid. org/0000-0001-7701-5583

(1999), Messer e Cohen (2004; 2007), and Breisinger et al. (2014) pointed out that violent conflicts lead to hunger and, conversely, food insecurity often precipitates violence. In addition, hunger and social, political, and economic instability, among other factors, are mutually reinforcing (WORLD FOOD PROGRAM USA, 2017). Cribb (2019, our translation) concludes that "The food system is, therefore, the cause, instrument, and victim of conflicts".

However, not all existing works in literature support this view of Buhaug et al. (2015) found that agricultural production and violent conflict are weakly and inconsistently linked. One of the key findings of the US World Food Program (WORLD FOOD PROGRAM USA, 2017) was that "hungry people are not always violent and violent people are not always hungry".

Indeed, food insecurity is rarely the only cause of violent conflict. Its combination with other factors (generally religious, political, or socioeconomic) is what usually precipitates the occurrence of civil unrest and wars (BRINKMAN; HENDRIX, 2011; WORLD FOOD PROGRAM USA, 2017; SOVA; FLOWERS; MAN, 2019). However, there are special cases in which food security, at macro and micro levels, is considered the main cause of conflicts, such as in the Arab world (MAYSTADT; TAN; BREISINGER, 2012) and in the Sahel region (SOVA; FLOWERS; MAN, 2019).

Furthermore, one cannot forget all the existing studies that deal with the effect of climate change on the increase in global conflicts. The most likely cause of the observed relationships lies, basically, in the negative impact that extreme weather has on the main drivers of food availability in certain countries in Africa and Asia (BUHAUG; GLEDITSCH; THEISEN, 2008; DAS, 2015; SOVA; FLOWERS; MAN, 2019; COHEN et al., 2020).

In this context, most of the literature addresses conceptual/empirical issues to understand the connections between food security and conflict. For this, hotspots are analyzed and several indicators are dissected to conjecture what led to the outbreak of the conflict (COHEN; PINSTRUP-ANDERSEN, 1999; MESSER, 2009; UPRETI; GHALE; GHIMIRE apud SABA et al., 2011; UNITED NATIONS, 2010; MESSER; COHEN, 2011; BUHAUG et al., 2015; GORDON et al., 2016). In other words, the literature tends to focus only on countries where conflicts and scarcity of natural resources prevail. From an analytical point of view, it is important to consider all cases (conflict and non-conflict) to establish a pattern/model. Otherwise, the analysis would be statistically biased concerning conflict cases, or, as they say in statistics, a class bias (GU; ZHOU; ZUO apud YIN; YAO; TINO, 2007). This is problematic because it makes false positives more likely, that is, if we were to predict whether a particular

country might come into conflict or not, we would be more likely to erroneously state that it would.

Few scientific articles use an extensive database from different countries and point out possible variables that can compose statistical models that predict the relationship between food security and conflicts (MAYSTADT; TAN; BREISINGER, 2012; DE GROEVE; VERNACCINI; HACHEMER, 2014; WORLD FOOD PROGRAM USA, 2017; MARTIN-SHIELDS; STOJETZ, 2019).

Thus, the objective of this work was to define the relationship between conflict and food security, at the macro level, using global indices (simple or composite) to cover as many countries as possible.

The focus on food is not intended to exclude other interpretations, but rather to add an often-overlooked dimension to our understanding of the origin of conflicts.

## 2 MATERIAL AND METHODS

The Global Peace Index (GPI, abbreviation for the index in English) was selected, as it assesses various forms of violence and conflicts. The GPI measures the level of negative peace in a country. It means that the lower the score, the more peaceful the country. It ranks 163 independent states and territories. It is based on three issues: ongoing domestic and international conflicts, the level of harmony or discord within a nation, and the militarization of a country. There are 23 indicators of the absence of violence or fear of violence. Details of the methodology are described by the Institute for Economics & Peace (2020).

The other selected variables represent a framework that tries to capture the social and institutional factors that make conflicts and violence more likely.

The literature points out that the main global drivers of conflict were poverty (for example, per capita income), socioeconomic inequalities, social fragmentation (for example, human rights abuse), poor governance, terrorism, and food insecurity (COHEN; PINSTRUP-ANDERSEN, 1999; BUHAUG; GLEDITSCH; THEISEN, 2008; UNITED NATIONS, 2010; MAYSTADT; TAN; BREISINGER, 2012; HENDRIX; BRINKMAN, 2013; PIAZZA, 2013; BREISINGER et al., 2014; GORDON et al., 2016; BELLINGER; KATTELMAN, 2020).

The Global Food Security Index (GFSI, abbreviation for the index in English) considers three issues: accessibility, availability, and quality. It also applies a risk adjustment factor based on natural resources and resilience. A set of 113 countries

was analyzed considering 34 food security indicators/drivers. The methodology involved in calculating the GFSI is described by The Economist Intelligence Unit (2019).

The Human Development Index (HDI) reveals the dynamics of governments (stability), education, health, and life expectancy in different types of economies. It ranks 189 independent countries and territories. It has five components: life expectancy at birth expected years of schooling, average years of schooling, gross national income (GDP) per capita, per capita GDP ranking minus HDI ranking itself. Details of the methodology are described in the United Nations Development Program – UNDP (2019).

The Sustainable Development Goals Index (SDG) tracks the country's performance on 17 targets with equal weights for all. The goal of these 17 goals is to end poverty. Various issues, from gender inequality to climate change, are assessed. The SDG Index ranks 166 independent states and territories. It includes 85 global indicators plus 30 additional indicators for countries participating in the Organization for Economic Cooperation and Development (OECD). Details of the methodology are described by Sachs et al. (2020).

To represent the economic wealth of a country, the Gross Domestic Product (GDP, abbreviation of the index in English) and the Gross Domestic Product per Capita (GDPPC, abbreviation of the index in English) indices were selected (THE WORLD BANK, 2020b). The main fact that led to this choice is found in the work of the World Food Program USA (2017), which found a significant negative relationship between the Gross Domestic Product and the armed conflict. Except for Venezuela (2014), the Republic of Yemen (2018), and the Syrian Arab Republic (2007), GDP and GDP Per Capita were obtained in 2019.

The GINI index is a statistical measure of a nation's income or wealth distribution (WORLD POPULATION REVIEW, 2020). It is sometimes also referred to as an indicator of inequality. The GINI index ranges from 0, representing perfect equality, to 1, representing extreme inequality. Except for Côte d'Ivoire (2015), Dominican Republic (2018), Guatemala (2014), Honduras (2018), and Uzbekistan (2000), the GINI index 2019 was selected.

Terrorism is strongly correlated with food production. Not only because terrorism harms a country's productive capacity, using food as a weapon (MESSER, 2009; BUREAU OF COUNTERTERRORISM, 2019; ADELAJA; GEORGE, 2019), but the food is often an important source of income or negotiation for terrorist groups (MESSER; COHEN, 2007; JAAFAR; WOERTZ, 2016; ADELAJA et al., 2019). That is why

terrorism will be considered in this study. The Global Terrorism Index (GTI) is based on the Global Terrorism Database, which comprises indicators of approximately 170,000 terrorist incidents. It ranks 163 independent states and territories. The GTI scores each country on a scale where 0 represents no impact and 10 represents the greatest measurable impact of terrorism. Details of the methodology are described by the Institute for Economics & Peace (2019).

Considering the overlapping of countries in the eight databases used, a total of 113 countries were the target of statistical analysis in this study.

To perform the statistical analyses, we used the statistical software R (IHAKA; GENTLEMAN, 1996) and its standard stats library, which provides functions for regression with classical or generalized models. In the classic scenario, it is assumed that the dependent random variable Y has a probability distribution with an expected value equal to $E[Y]=\beta_0+\beta_1 X_1+\beta_2 X_2+...+\beta_n X_n$ in which $\beta_i$ are coefficients to be estimated by the method of least squares, and $X_i$ it is the independent deterministic variables that are observed. to estimate $\beta_i$, no assumptions about the type of distribution of Y are needed. However, to obtain confidence intervals, it is necessary to assume that the distribution is normal (see Chapter 7 of JOHNSON; WICHERN, 2002). To assess the goodness of fit of the regression curve, the $R^2$ statistic was used, which measures the proportion of variance of the items in the data set. $\{Y_1, Y_2..., Y_K\}$ which is explained when considering its dependence on independent variables. A confidence interval for $R^2$ is obtained by (see chapter 3 of COHEN et al., 2013):

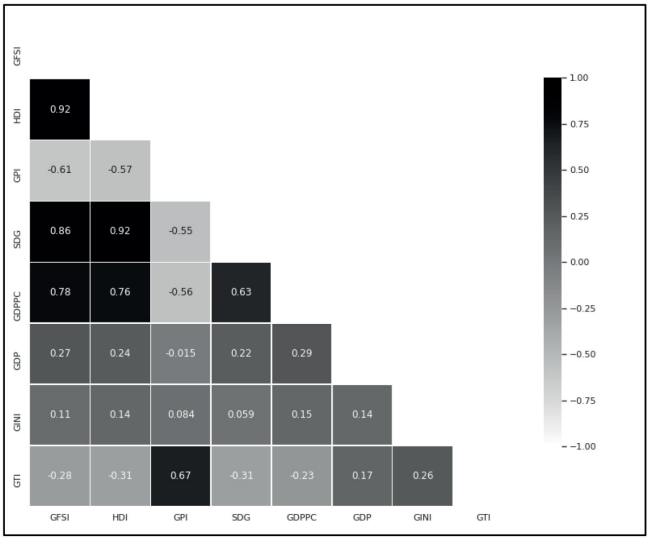
$$R^2 \sqrt{\frac{4R^2(1-R^2)^2(n-k-1)^2}{(n^2-1)(n+3)}}$$

Generalized linear models are an extension of the model above. Among the differences, the most important are: i) the variance of Y can change depending on the independent variables; and ii) assumptions other than Y normality are used to calculate $R^2$, which sometimes produces more realistic values. This model also allows E[Y] to have non-linear relationships with the independent variables, but in this work, linearity is assumed unless otherwise mentioned.

## 3 RESULTS

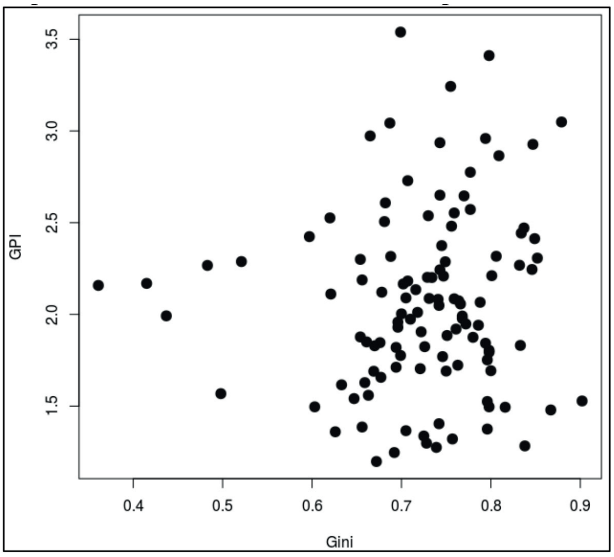
Figure 1 shows the correlation between all indices used in this study. The Global Peace Index (GPI) correlated significantly (P<0.01) with the Global Food Security Index (GFSI), the Human Development Index (HDI), the Sustainable Development Goals (SDG), the Domestic Product Gross per capita (GDPPC), and the Global Terrorism Index (GTI). Naturally, the GPI and GTI are positively correlated, as a higher terrorism rate implies a higher (ie worse) peace rate. Surprisingly, the GPI does not correlate with the GINI coefficient, which seems to indicate that wealth inequality has no bearing on levels of peace within a country. Correlating the GPI against the GINI coefficient for several countries did not reveal any kind of complex mathematical relationship that could not be detected by the correlation, as shown in figure 2. The only conclusion that can be reached is that countries with low inequality (GINI <0.5) have lower GPI values (ie, better), although they are not the lowest among all others.

**Figure 1 – Heatmap of all correlations between the studied indices**




**Source:** THE AUTHORS, 2021.

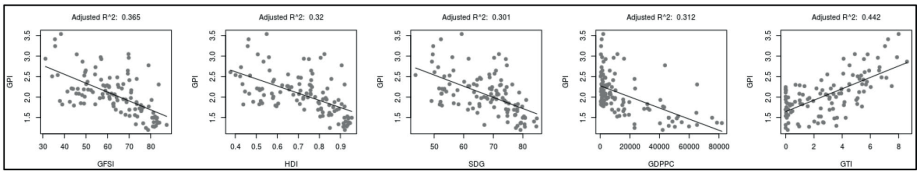
**Figure 2 – Graph showing the relationship between the Global Peace Index (GPI) and the GINI coefficient of 113 countries. No mathematical relationship seems to be visible**




**Source:** THE AUTHORS, 2021.

Figure 3 shows the graphs of the relationships between the GPI against the aforementioned indices that demonstrated the highest correlation (Figure 1) and includes the goodness-of-fit when considering a linear regression model on the data. The R2 statistic (JOHNSON; WICHERN, 2002) informs that the GTI and the GFSI are the covariates with the most deterministic mathematical relationship concerning the GPI, although some noise still exists. However, this analysis is probably underestimated for Gross Domestic Product Per Capita (GDPPC), as its relationship to the GPI appears to be non-linear. If linear regression is performed with √(GDPPC), the R2 statistic increases to 0.3435.

**Figure 3 – Graphs of the relationship between the GPI against each of the indexes that showed a high correlation. The black line shows a linear regression model applied to the data.**




**Source:** THE AUTHORS, 2021.

We now analyze the slope of these regression curves, which is not properly captured by $R^2$, since determinism is not related to the slope $\beta_i$ . Based on the assumptions of the simple linear regression model $Y = \beta_1 X + \beta_0$ it is possible to determine confidence intervals for the slope (JOHNSON; WICHERN, 2002). Even so, due to the disparity in the range of values assumed by each covariate (for example, independent variable), the slopes of the curves cannot be directly compared with each other. To overcome this difficulty, it is common to normalize the data. For this, normalization was used through the "Z score" (KOTSIANTIS; KANELOPOULOS; PINTELAS, 2006) which occurs through the expression

$$\frac{x - \hat{\mu}}{\hat{\sigma}}$$

in which $\hat{\mu}$ e $\hat{\sigma}$ are the sample mean and standard deviation, respectively. With this normalization, the confidence interval for slope 1 of the curve is obtained, as shown in Table 1. These results are a reflection of the correlations shown in figure 1. With these intervals, it is possible to conclude with due significance statistics. For example, it is notable that the GTI is the most impactful independent variable in the regressions presented against the GPI, while all other variables are within the margin of error of each other. In these circumstances, the GTI must be chosen to model the GPI and the selection of the other independent variables can be refined by choosing the more deterministic ones, as assessed using the $R^2$.

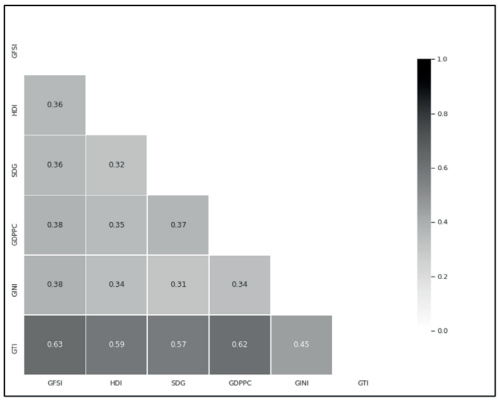
**Table 1 – 90% confidence interval for the slopes 1 of the straight lines, after performing the normalization. Numbers rounded to three significant digits**

| Covariate | $\beta_1$ |
|---|---|
| GFSI | [−0,633; −0,585] |
| HDI | [−0,596; −0,546] |
| SDG | [−0,580; −0,529] |
| √(GDPPC) | [−0,616; −0,567] |
| GTI | [0,646; 0,691] |

**Source:** THE AUTHORS, 2021.

The $R^2$ obtained from the linear regression, using all covariate combinations, is shown in figure 4. The GFSI with the GTI seems to be the best choice, followed by the GDPPC combination with the GTI. From the GTI line, in figure 4, all covariates, except the GINI, pass the Akaike information criterion test (JOHNSON; WICHERN, 2002) to add the covariate to the regression. The same happens when performing a stepwise regression at a 5% significance level. That is, only the GINI fails the test. There is also no non-linear relationship when viewing the GPI versus the GTI and the GINI, which is more similar to a linear relationship that presents a large amount of noise. Note that, in this analysis, the square root of the GDPPC was not used, as such a transformation was not shown to be beneficial.

**Figure 4 – $R^2$ values adjusted when performing linear regression using each pair of covariates**




**Source:** THE AUTHORS, 2021.

Considering that the GTI, GDP, PC, and GFSI reached the best values of R2 and, also, that such indexes were the most impacting factors in the GPI, as discussed above, it is reasonable to choose them as covariates to predict the GPI. By repeatedly applying stepwise addition and removal of variables, one obtains that the best model for the GPI is given by:

$$Y_{GPI} = -0.0413X_{GTI} - 4.55\cdot 10^{-6} X_{GDPPC} + 3.86\cdot 10^{-4} X_{GTI} X_{GFSI}$$
$$-8.37\cdot 10^{-7} X_{GTI} X_{GDPPC} + 1.16\cdot 10^{-7} X_{GFSI} X_{GDPPC} + 0.524$$

which results in an adjusted $R^2$ of 71.4%, using a generalized linear model of the Gaussian type. With such a high level of coefficient of determination, it is reasonable to conclude that GPI is a function of GTI, GDPPC e GFSI. Furthermore, they have a high impact on the GPI, as discussed earlier.

When considering the GTI and the GFSI, but taking each component of the GFSI separately, the results shown in Table 2 are obtained. The data from R2 suggest that Availability has the greatest weight in the statistical model that governs the relationship between the GPI and the GFSI. Furthermore, analyzing the slope of the regression curve, the data support the fact that Availability has the greatest influence on the GPI, with a slope of -0.0259, followed by Natural Resources and

Resilience, with a slope of - 0.0234, Accessibility, with -0.0173, and Quality and Safety, with -0.0128.

**Table 2 – Coefficient of determination R2 when performing a regression where the dependent variable is the GPI and the covariates are the GTI associated with each of the four GFSI subcomponents, listed in the left column. Numbers are rounded to three significant digits**

| **Covariate** | $R^2$ |
|---|---|
| Availability | 0,663 |
| Accessibility | 0,595 |
| Quality and safety | 0,551 |
| Natural Resources and Resilience | 0,533 |

**Source:** THE AUTHORS, 2021.

## 4 DISCUSSION

Comparatively, less attention has been paid to the implications of food insecurity for political instability and violence in the world (BRINKMAN; HENDRIX, 2010), mainly because food insecurity dropped dramatically across the world from 1991 to 2017 (BRÜCK; D' ERRICO, 2019). However, since 2017, the numbers of food insecurity and the amount of conflict have increased dramatically in the world (FAO et al., 2020; WPF; FAO, 2020).

The Global Peace Index (GPI) measures more than just the presence or absence of war. It captures the absence of violence or fear of violence (INSTITUTE FOR ECONOMICS & PEACE, 2020). The events considered in the GPI are hardly interpreted based on single models alone. However, it seems that the observed dynamic is partially related to some “classic” elements. Naturally, the GPI and GTI are positively correlated, as a higher terrorism rate implies a higher (ie worse) peace rate. It is really surprising to observe this relationship even after the major attacks on international terrorist organizations in 2019 (BUREAU OF COUNTERTERRORISM, 2020). However, this result emphasizes the relevance of the persistence of terrorism

in important strongholds such as Nigeria, for example (MUHAMMAD; LIMAN, 2019; JOHNSON, 2020).

Furthermore, it is a surprise that the GPI does not correlate with the GINI coefficient, which seems to indicate that wealth inequality has no bearing on levels of peace within a country.

However, terrorism (GTI) is not enough to explain, statistically, the beginning of conflicts. Other aspects that emerged from this study bring out that food safety (GFSI) also affects the GPI. Rising prices or insufficient food production (Accessibility or Availability, respectively) may be the main contributors (BRINKMAN; HENDRIX, 2010; PAVELIUC-OLARIU, 2013; BRÜCK; D'ERRICO, 2019). However, our results show that Availability was statistically more significant. This probably reflects the effect of drought and the largest locust attack event recorded since 2019 in East Africa, which reached Pakistan and India in Asia (CHAPUIS; PIOU, 2020; FAO, 2020).

In the context analyzed, the idea of the influence of the economic income group (measured by GDP per capita – GDPPC) is suggestive and significant. It represents the Poverty factor claimed by several authors as the link between civil conflict and chronic food insecurity (COLLIER et al., 2003; BLATTMAN; MIGUEL, 2010; SOVA; FLOWERS; MAN, 2019; BELLINGER; KATTELMAN, 2020).

## 5 FINAL CONSIDERATIONS

Several theories have been proposed to explain global conflicts, but each focuses on particular aspects of processes that occur in a particular country or small group of countries in conflict situations. In the present work, we tried to understand how conflicts arise using global datasets. Indeed, data analysis suggests that such conflicts can be better explained if we consider the interactions between terrorism, food security, and per capita income. This multiplicity of factors confirms the greater complexity of the model and R2 predicts that 71.4% of cases can be explained by the model developed here. Thus, the other 28.6% probably refer to specific causes in the region in conflicts, such as religion or ethnicity.

We believe that food security is a geopolitical, economic, and environmental engine that has shaped and will still shape the contours of global violence and conflict shortly.

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